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DOCUMENT

# ExoMars 2016 Mission
# Brief description of TGO and Schiaparelli

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**Reference** EXM-MS-REP-RSSD-001_TGO-EDM-Description_Iss.1
**Issue** 1
**Revision** 0
**Date of Issue** 28/01/2016
**Status** 1
**Document Type** RP
**Distribution**

# CHANGE LOG

| Reason for change | Issue | Revision | Date |
|---|---|---|---|
| Original issue | 1 | 0 | 4/02/2016 |

# CHANGE RECORD

| Issue 1 | Revision 0 | | |
|---|---|---|---|
| **Reason for change** | **Date** | **Pages** | **Paragraph(s)** |
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# 1 INTRODUCTION

This document presents a brief summary of the ExoMars 2016 mission and its two major elements, the Trace Gas Orbiter, TGO, and the Entry descent and landing Demonstrator Model, EDM, - Schiaparelli. It also gives an overview of the TGO and Schiaparelli scientific investigations and the corresponding instruments. The text is derived from information available on the ESA Exploration web-site, http://exploration.esa.int/mars/. The website is providing the latest up to date information on the mission and is following its evolution, while it is not intended to update this document after its first issue.

# 2 EXOMARS TRACE GAS ORBITER AND SCHIAPARELLI MISSION (2016)

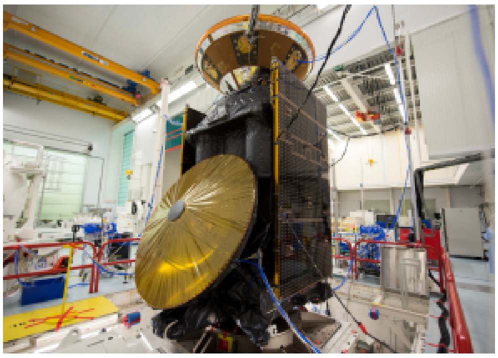
The first mission of the ExoMars programme, scheduled to arrive at Mars in 2016, consists of a Trace Gas Orbiter plus an entry, descent and landing demonstrator module, known as Schiaparelli. The main objectives of this mission are to search for evidence of methane and other trace atmospheric gases that could be signatures of active biological or geological processes and to test key technologies in preparation for ESA's contribution to subsequent missions to Mars.

The Orbiter and Schiaparelli will be launched together in March 2016 on a Proton rocket and will fly to Mars in a composite configuration. By taking advantage of the positioning of Earth and Mars the cruise phase can be limited to about 7 months, with the pair arriving at Mars in October. Three days before reaching the atmosphere of Mars, Schiaparelli will be ejected from the Orbiter towards the Red Planet. Schiaparelli will then coast towards its destination, enter the Martian atmosphere at 21 000 km/h, decelerate using aerobraking and a parachute, and then brake with the aid of a thruster system before landing on the surface of the planet. From its coasting to Mars till its landing, Schiaparelli will communicate with the Orbiter. Once on the surface, the communications of Schiaparelli will be supported from a NASA Relay Orbiter and from Mars Express. The ExoMars Orbiter will be inserted into an elliptical orbit around Mars and then sweep through the atmosphere to finally settle into a circular, approximately 400-km altitude orbit ready to conduct its scientific mission.

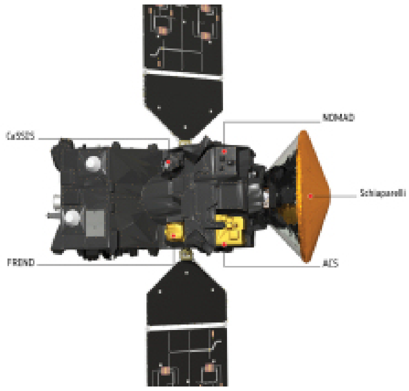
*ExoMars 2016: Trace Gas Orbiter and Schiaparelli.*
*Credit: ESA/ATG medialab*

**Trace Gas Orbiter - Searching for signature gases in the Martian atmosphere**

The Orbiter spacecraft is designed by ESA, while Roscosmos provides the launch vehicle. A scientific payload with instruments from Russia and Europe will be accommodated on the Orbiter to achieve its scientific objectives. The Orbiter will perform detailed, remote observations of the Martian atmosphere, searching for evidence of gases of possible biological importance, such as methane and its degradation products. The instruments onboard the Orbiter will carry out a variety of measurements to investigate the location and nature of sources that produce these gases. The scientific mission is expected to begin in December 2017 and will run for five years. The Trace Gas Orbiter will also be used to relay data for the 2018 rover mission of the ExoMars programme and until the end of 2022.



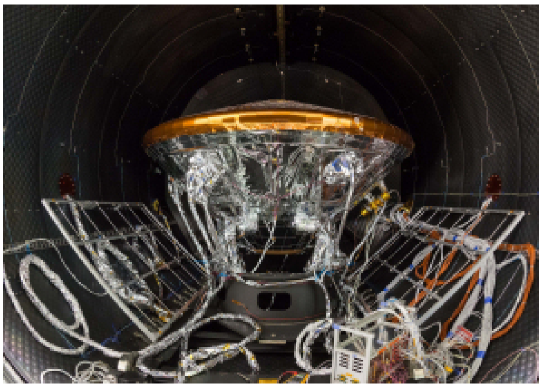
*ExoMars Trace Gas Orbiter and Schiaparelli during vibration testing.*
*Credit: ESA–S. Corvaja, 2015*



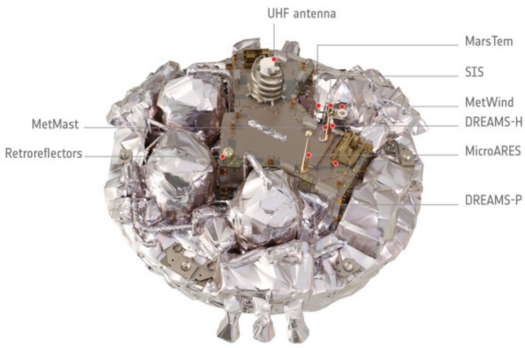

*ExoMars 2016: Trace Gas Orbiter and Schiaparelli.*
*Credit: ESA/ATG medialab*

**Schiaparelli: an entry, descent and landing demonstrator module**
**Testing critical technology for future missions**

Schiaparelli, the ExoMars entry, descent and landing demonstrator module will provide Europe with the technology for landing on the surface of Mars with a controlled landing orientation and touchdown velocity. The design of Schiaparelli maximises the use of technologies already in development within the ExoMars programme. These technologies include: special material for thermal protection, a parachute system, a radar Doppler altimeter system, and a final braking system controlled by liquid propulsion.



*Schiaparelli prepares for thermal tests.*
*Credit: ESA – B. Bethge*




*Schiaparelli - without heat shield and back cover.*
*Credit: ESA/ATG medialab*

Schiaparelli is expected to survive on the surface of Mars for a short time by using the excess energy capacity of its batteries. The science possibilities of Schiaparelli are limited by the absence of long term power and the fixed amount of space and resources that can be accommodated within the module; however, a set of scientific sensors will be included to perform limited, but useful, surface science.

| ExoMars 2016 Mission Phases Overview | |
|---|---|
| **Launch Period** | 14-25 March 2016 |
| **Schiaparelli – Trace Gas Orbiter separation** | 16 October 2016 |
| **Trace Gas Orbiter insertion into Mars orbit** | 19 October 2016 |
| **Schiaparelli enters Martian atmosphere and lands on the target site** | 19 October 2016 |
| **Schiaparelli science operations** | 19 October - 23 October 2016 (to be confirmed) |
| **Trace Gas Orbiter changes inclination to science orbit (74°)** | December 2016 |
| **Apocentre reduction manoeuvres (from the initial 4-sol orbit to a 1-sol orbit)** | December 2016 |
| **Aerobraking phase (Trace Gas Orbiter lowers its altitude to a 400 km circular orbit)** | January 2017 - December 2017 |
| **Trace Gas Orbiter science operations begin. (In parallel, TGO will start data relay operations to support NASA landers on Mars.)** | December 2017 |
| **Superior solar conjunction (critical operations are paused while the Sun is between Earth and Mars)** | 11 July - 11 August 2017 |
| **Start of the Trace Gas Orbiter data relay operations to support communications for the rover mission and for the surface science platform** | 15 January 2019 |
| **End of Trace Gas Orbiter mission** | December 2022 |

## Keeping in touch far from home

After launch and throughout the cruise phase, the spacecraft unit made up of the Trace Gas Orbiter and Schiaparelli is operated by ESA through the space communications network of ESA's European Space Operations Centre (ESOC).

After separation, the Orbiter will monitor the UHF transmission from Schiaparelli from its coasting to Mars till its landing. A NASA Relay Orbiter will act as a data relay for Schiaparelli during its surface operations. Furthermore, ground-based communication arrays will also track the UHF signal during the entry, descent and landing phases.

ESA will be in full control of the Orbiter during all phases of its mission, including insertion into Mars orbit, orbit control, aerobraking, science operations and Mars communications operations.

# 3 EXOMARS TRACE GAS ORBITER (TGO)

**Searching for signature gases in the Martian atmosphere**

The 2016 ExoMars Trace Gas Orbiter is the first in a series of Mars missions to be undertaken jointly by the two space agencies, ESA and Roscosmos. A key goal of this mission is to gain a better understanding of methane and other atmospheric gases that are present in small concentrations (less than 1% of the atmosphere) but nevertheless could be evidence for possible biological or geological activity.

*ExoMars Orbiter in cruise configuration. Credit: ESA*

Investigations with observatories in space and on Earth have demonstrated the presence of small amounts of methane in the Martian atmosphere that has been shown to vary with location and time. Since methane is short-lived on geological time scales, its presence implies the existence of an active, current source of methane. It is not clear, yet, whether the nature of that source is biological or chemical. Organisms on Earth release methane as they digest nutrients. However, other purely geological processes, such as the oxidation of certain minerals, also release methane.

The Trace Gas Orbiter will carry a scientific payload capable of addressing this scientific question, namely the detection and characterisation of trace gases in the Martian atmosphere. From its approximately 400-km altitude science orbit, the instruments onboard the Trace Gas Orbiter will be deployed to detect a wide range of atmospheric trace gases (such as methane, water vapour, nitrogen oxides, acetylene), with an improved accuracy of three orders of magnitude compared to previous measurements.

The Trace Gas Orbiter will monitor seasonal changes in the atmosphere’s composition and temperature in order to create and refine detailed atmospheric models. Its instruments will also map the subsurface hydrogen to a depth of a metre, with improved spatial resolution compared with previous measurements. This could reveal deposits of water-ice hidden just below the surface, which, along with locations identified as sources of the trace gases, could influence the choice of landing sites of future missions.

# 4 EXOMARS TRACE GAS ORBITER INSTRUMENTS

## Investigating the Martian atmosphere

The Trace Gas Orbiter will accommodate scientific instruments for the detection of trace gases with an improved accuracy of three orders of magnitude compared to previous measurements from orbit and ground-based measurements. It will also provide new data for the study of the temporal and spatial evolution of trace gases in the Martian atmosphere, and for the location of their source regions.
Additionally, data on the distribution of aerosols and temperatures, together with computer modelling will allow an improved understanding of the atmospheric circulation and its seasonal variations. This will help determine whether particular gases are emanating from specific areas on Mars and to provide insights into the nature of the trace gas source.
The scientific payload operations of the Orbiter will start in 2017 and are planned to last for a minimum of one Martian year (687 Earth days).

The Orbiter will be used to investigate the atmosphere and the surface of Mars with the following scientific objectives:

- **Deliver a detailed characterisation of the Martian atmosphere's composition**.
  This includes mapping the distribution of trace gases, identifying their sources and sinks, and studying geographical and temporal variability. The first scientific goal will be to detect a broad suite of atmospheric trace gases, and key isotopologues (molecules that have at least one atom with a different number of neutrons than the parent molecule), to establish the atmospheric inventory. Following a positive detection of key species, geographical (location and altitude) and seasonal mapping will be carried out. Mapping of the Deuterium/Hydrogen ratio will also be performed, to provide new information on water reservoirs and atmospheric escape. A third goal is characterising the state of the atmosphere, in particular temperatures, aerosols, water vapour, and ozone.

- **Imaging of surface features**
  Image and characterise features on the Martian surface which may be related to trace gas sources. The data should provide information on the geological and dynamical context (such as volcanism) for any sources detected.

- **Mapping of subsurface hydrogen**
  Map the subsurface hydrogen to a depth of one metre, with a significantly improved resolution compared to previous measurements.

## Instruments in brief

The Trace Gas Orbiter, manufactured in Europe, will carry a science payload of four instruments:

| **NOMAD** – **N**adir and **O**ccultation for **MA**rs **D**iscovery |
|---|
| NOMAD combines three spectrometers, two infrared and one ultraviolet, to perform high-sensitivity orbital identification of atmospheric components, including methane and many other species, via both solar occultation and direct reflected-light nadir observations. |
| *Principal Investigator:* Ann Carine Vandaele, Belgian Institute for Space Aeronomy, Belgium<br>*Co-Principal Investigator:* José Lopez Moreno, Instituto de Astrofísica de Andalucía, Spain<br>*Co-Principal Investigator:* Giancarlo Bellucci, Istituto Nazionale di Astrofisica, Italy<br>*Co-Principal Investigator:* Manish Patel, The Open University, United Kingdom<br>*Participating countries:* Belgium, Spain, Italy, United Kingdom, United States of America, Canada. |

| **ACS**– **A**tmospheric **C**hemistry **S**uite |
|---|
| This suite of three infrared instruments will help scientists to investigate the chemistry and structure of the Martian atmosphere. ACS will complement NOMAD by extending the coverage at infrared wavelengths, and by taking images of the Sun to better analyse the solar occultation data. |
| *Principal Investigator:* Oleg Korablev, Space Research Institute (IKI), Moscow, Russia |

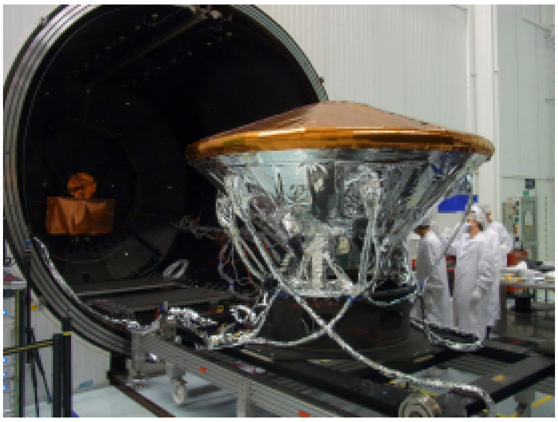
| **CaSSIS – C**olour **a**nd **S**tereo **S**urface **I**maging **S**ystem |
|---|
| A high-resolution camera (5 metres per pixel) capable of obtaining colour and stereo images over a wide swathe. CaSSIS will provide the geological and dynamical context for sources or sinks of trace gases detected by NOMAD and ACS. |
| *Principal Investigator*: Nicolas Thomas, University of Bern, Switzerland<br>*Participating countries:* Switzerland, Italy. |

| **FREND – F**ine **R**esolution **E**pithermal **N**eutron **D**etector |
|---|
| This neutron detector will map hydrogen on the surface down to a metre deep, revealing deposits of water-ice near the surface. FREND's mapping of shallow subsurface water ice will be up to 10 times better than existing measurements. |
| *Principal Investigator:* Igor Mitrofanov, Space Research Institute (IKI), Moscow, |

# 5 SCHIAPARELLI: THE EXOMARS ENTRY, DESCENT AND LANDING DEMONSTRATOR MODULE

### Schiaparelli, the European Perspective

One of the core scientific goals of any mission to Mars is the search for evidence of life. The best approach is to investigate the surface where the evidence may lie.

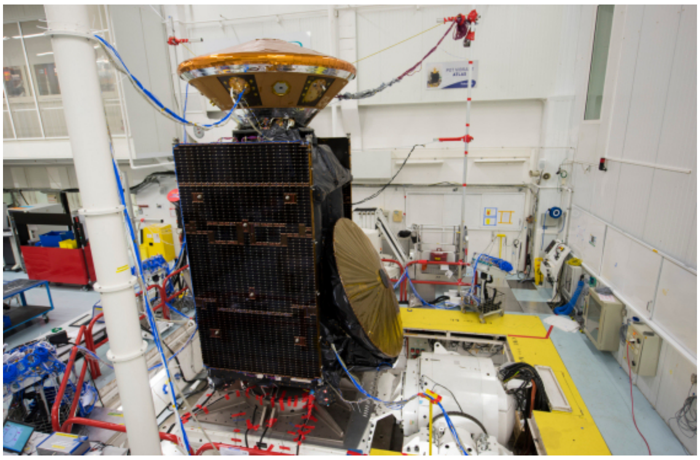


*Schiaparelli prepares for thermal tests.*
*Credit: ESA – B. Bethge*

The key element for accessing the surface of Mars and one of the greatest challenges in space exploration is the successful execution of the entry, descent and landing sequence.

This is one of the reasons why since the late 1960s there have been so many missions attempting to land on the surface of Mars, some being successful, many others ill-fated.

Schiaparelli - an entry, descent and landing demonstrator module - is a technology demonstration vehicle carried by the ExoMars Trace Gas Orbiter, which will be launched in 2016 to demonstrate the capability of ESA and the European industry to perform a controlled landing on the surface of Mars. The preparation for this mission enhances Europe's expertise and enables the testing of key technologies which could be used in subsequent missions to Mars.



*The ExoMars Trace Gas Orbiter and Schiaparelli during vibration testing.*
*Credit: ESA–S. Corvaja, 2015.*

Although designed to demonstrate entry, descent and landing technologies, Schiaparelli also offers limited, but useful, science capabilities. It will deliver a science package that will operate on the surface of Mars for a short duration after landing, planned to last approximately 2-4 sols (martian days).

**Arriving at Mars**

Schiaparelli will start its journey to Mars in March 2016 attached to the Trace Gas Orbiter. They will be launched on a Proton rocket and will arrive approximately 7 months later at Mars.

**Coast**

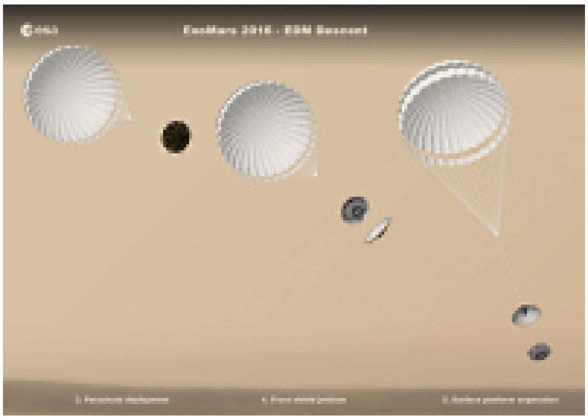
- Three days before reaching the atmosphere of Mars, Schiaparelli will separate from the Orbiter.
- The module will then coast to Mars during which phase it will remain in hibernation mode in order to reduce its power consumption.
- Schiaparelli will be activated a few hours before entering the atmosphere of Mars, at an altitude of 122.5 km and a speed of approximately 21 000 km/h.

**Entry**

*Schiaparelli, an entry, descent and landing demonstration module, depicted during the 'entry phase'.*
*Credit: ESA*

- An aerodynamic heatshield will protect Schiaparelli from the severe heat flux and deceleration, so that at an altitude of about 11 km, when the parachute is deployed, it will be travelling at around 1650 km/h.

## Descent



*Schiaparelli in the 'descent phase'.*
*Credit: ESA*

- The module will first release the front heatshield and then the rear heatshield will also be jettisoned.
- Schiaparelli will turn on its Doppler radar altimeter and velocimeter to locate its position with respect to the Martian surface.

## Landing

*Schiaparelli in the 'landing phase'.*
*Credit: ESA*

- The liquid propulsion system will be activated to reduce the speed to less than 2 m/s when it is 2m above the ground. At that moment the engines will the switched off and the lander will drop to the ground.
- As Schiaparelli lands, the final shock will be cushioned by a crushable structure built into module.
- The primary landing site has been identified: it is a plain known as Meridiani Planum. This area interests scientists because it contains an ancient layer of hematite, an iron oxide that, on Earth, almost always forms in an environment containing liquid water.

A communication link between Schiaparelli and the Trace Gas Orbiter will facilitate the real-time transmission of the most important data measured by the module. The complete set of data acquired will be transmitted to the Orbiter within 8 sols after the landing (a solar day on Mars, or sol, is 24 hours and 37 minutes). The Schiaparelli mission then comes to an end.

| Descent and landing at a glance |
|---|
| Three days before reaching Mars, Schiaparelli will separate from the Trace Gas Orbiter and coast towards the planet in hibernation mode, to reduce its power consumption. |
| Schiaparelli will be activated a few hours before entering the atmosphere of Mars at an altitude of 122.5 km and a speed of 21 000 km per hour. |
| An aerodynamic heatshield will slow the lander down such that at an altitude of about 11 km, when the parachute is deployed, it will be travelling at around 1650 km per hour. |
| Schiaparelli will release its front heatshield at an altitude of about 7 km and turn on its radar altimeter, which can measure the distance to the ground and its velocity relative to the surface. This information is used to activate and command the liquid propulsion system once the rear heatshield and parachute have been jettisoned 1.3 km above the surface. |
| At this point, Schiaparelli will still be travelling at nearly 270 km per hour, but the engines will slow it to less than 2 m/s by the time it is 2 m above the surface. |
| At that moment, the engines will be switched off and Schiaparelli will free-fall to the ground, where the final impact, at just under 11 km per hour, will be cushioned by a crushable structure on the base of the lander. |
| Schiaparelli will arrive at Mars during the global dust storm season, which means that it may encounter a highly dust-loaded atmosphere. |
| The heat shield surface temperature during entry reaches approximately 1500°C. |
| The landing is controlled but not guided, and the module has no obstacle avoidance capability |
| Schiaparelli will target a landing site on the plain known as Meridiani Planum |
| Schiaparelli will be designed to land on a terrain with rocks as high as 40 cm and slopes as steep as 12.5°. |

## The ExoMars Schiaparelli Design

Schiaparelli builds on a heritage of designs that have been evaluated and tested by ESA during earlier ExoMars studies. The module accommodates a series of sensors that will monitor the behaviour of all key technologies during the mission. These technologies include a special material for thermal protection, a parachute system, a radar Doppler altimeter system, and a braking system controlled by liquid propulsion. The data will be sent back to Earth for post-flight reconstruction in support of future European missions to Mars.
The main characteristics of Schiaparelli are provided in the table below:

| Main technical characteristics of Schiaparelli – the ExoMars Entry, Descent and Landing Demonstrator Module | |
|---|---|
| **Diameter** | 2.4 m with heatshield, 1.65 m without heatshield |
| **Mass** | 600 kg |
| **Heat shield material** | Norcoat Liege |
| **Structure** | Aluminium sandwich with Carbon Fibre Reinforced Polymer skins |
| **Parachute** | Disk-Gap-Band canopy, 12 m diameter |
| **Propulsion** | 3 clusters of 3 hydrazine engines (400 N each), operated in pulse-modulation |
| **Power** | Primary batteries |
| **Communications** | UHF link with the ExoMars Orbiter (with 2 antennas) |

The design activities are performed by European industry, led by Thales Alenia Space – Italy under the close supervision of ESA.

# 6 SCHIAPARELLI SCIENCE PACKAGE AND SCIENCE INVESTIGATIONS

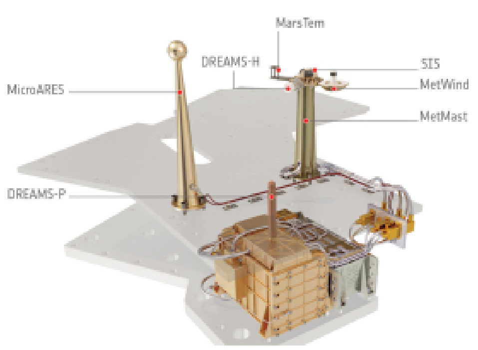
Because Schiaparelli is primarily demonstrating technologies needed for landing, it does not have a long scientific mission lifetime: it is intended to survive on the surface for just a few days by using the excess energy capacity of its batteries. However, a set of engineering and scientific sensors will analyse the local environment during descent and after landing.

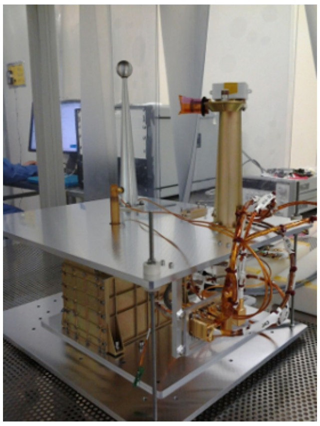
Science investigations to be carried on Schiaparelli were selected in June 2011 following an announcement of opportunity released by ESA and NASA.
The selected investigations consist of a surface payload, called DREAMS, which will operate on the surface of Mars for 2–8 sols, and an investigation known as AMELIA, for entry and descent science investigations using the spacecraft engineering sensors.
A separate instrumentation package, COMARS+, will monitor the heat flux on the back cover of Schiaparelli as it passes through the atmosphere.
In addition, the Descent Camera (DECA) on Schiaparelli will image the landing site as it approaches the surface, as well as providing a measure of the atmosphere's transparency. DECA is the re-named flight spare of the visual monitoring camera which flew on Herschel.
A compact array of laser retroreflectors is attached to the zenith-facing surface of Schiaparelli. This can be used as a target for future Mars orbiters to laser-locate the module.

## DREAMS: the Schiaparelli surface payload

The Schiaparelli surface payload, known as the DREAMS (Dust Characterisation, Risk Assessment, and Environment Analyser on the Martian Surface) package, consists of a suite of sensors to measure the wind speed and direction (MetWind), humidity (DREAMS-H), pressure (DREAMS-P), atmospheric temperature close to the surface (MarsTem), the transparency of the atmosphere (Solar Irradiance Sensor, SIS), and atmospheric electrification (Atmospheric Radiation and Electricity Sensor; MicroARES).

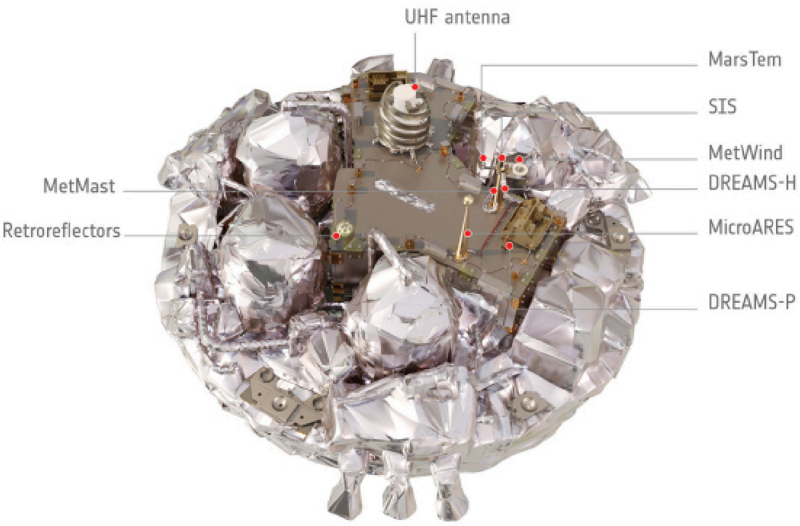
*The DREAMS science package accommodated on the Schiaparelli surface platform: schematic drawing and photograph of flight model.*



*Credit schematic drawing: ESA/ATG medialab; Credit photo: ASI & DREAMS Team (INAF, Napoli, Italy; CISAS, Padova, Italy; LATMOS, France; ESA-ESTEC, Noordwijk; Oxford University, United Kingdom; FMI, Finland; INTA, Spain)*

DREAMS will provide the first measurements of electric fields on the surface of Mars (with MicroARES). Combined with measurements (from SIS) of the concentration of atmospheric dust, DREAMS will provide new insights into the role of electric forces on dust lifting, the mechanism that initiates dust storms.
In addition, the DREAMS-H sensor will complement MicroARES measurements with critical data about humidity; this will enable scientists understand better the dust electrification process.




*Schiaparelli - without heat shield and back cover. Credit: ESA/ATG medialab*

**DREAMS sensors in brief**

| |
|---|
| *Principal Investigator:*<br>Francesca Esposito, INAF - Osservatorio Astronomico di Capodimonte, Naples, Italy<br>*Co-Principal Investigator:*<br>Stefano Debei, CISAS, Università di Padova, Italy<br>*Project Manager:*<br>Carlo Bettanini, CISAS, Università di Padova, Italy |
| **MetWIND**<br>Wind sensor |
| *Lead Co-Investigator:* Colin Wilson, University of Oxford, United Kingdom |
| *Participating countries:* Italy, United Kingdom |
| **DREAMS-H**<br>Humidity sensor |
| *Lead Co-Investigator:* Ari-Matti Harri, Finnish Meteorological Institute, Finland |
| *Participating countries:* Italy, Finland |

| |
|---|
| **DREAMS-P**<br>Pressure sensor |
| *Lead Co-Investigator:* Ari-Matti Harri, Finnish Meteorological Institute, Finland |
| *Participating countries:* Italy, Finland |
| **MarsTem**<br>Temperature sensor |
| *Lead Co-Investigator:* Giacomo Colombatti, CISAS, Università di Padova, Italy |
| *Participating countries:* Italy |
| **SIS – Solar Irradiance Sensor**<br>Optical depth single sensor – This will measure the concentration of atmospheric dust |
| *Lead Co-Investigator:* Ignacio Arruego, INTA, Madrid, Spain |
| *Participating countries:* Italy, Spain |
| **MicroARES**<br>Atmospheric charging – This sensor will provide the first measurements of the electric fields on the surface of Mars |
| *Lead Co-Investigators:* Franck Montmessin, LATMOS, France; Olivier Witasse, ESA-ESTEC, Noordwijk, The Netherlands |
| *Participating countries:* Italy, France, the Netherlands |

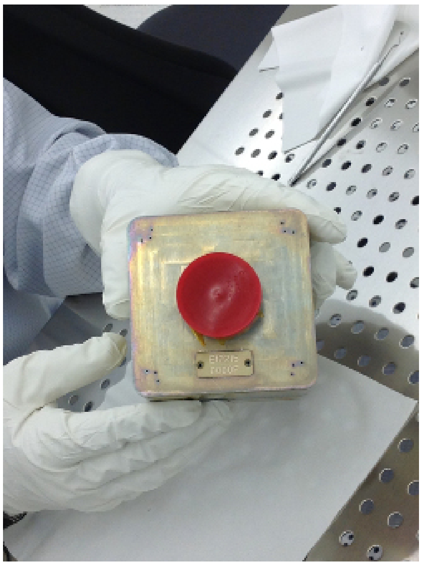
**AMELIA: Schiaparelli entry and descent science investigations**
The Schiaparelli Entry and Descent Science Team, will carry out a programme, known as AMELIA (Atmospheric Mars Entry and Landing Investigation and Analysis), to study Schiaparelli's engineering data to reconstruct its trajectory and determine atmospheric conditions, such as density and wind, from a high altitude to the surface. These measurements are key to improving models of the Martian atmosphere.

| |
|---|
| *Principal Investigator:*<br>Francesca Ferri, Università di Padova, Italy |
| *Co-Principal Investigator (modelling):*<br>François Forget, Laboratoire de Météorologie Dynamique, France<br>*Co-Principal Investigator (pressure and radio link science):*<br>Özgür Karatekin, Royal Observatory of Belgium, Belgium<br>*Co-Principal Investigator (assimilation):*<br>Stephen Lewis, The Open University, United Kingdom |
| *Participating countries:* Italy, France, Belgium, United Kingdom, United States of America, Germany, Finland |

## DECA: the Descent Camera on Schiaparelli

DECA is the flight spare of the visual monitoring camera, which flew on the Herschel spacecraft. This camera (mass of 0.6 kg and dimensions of about 9 cm × 9 cm × 9 cm) will be used to perform high-resolution imaging of the Schiaparelli landing site, to determine the transparency of the Martian atmosphere, and to support the generation of a 3-D topography model of the surface of the landing region.

DECA will start taking images after the front-shield of Schiaparelli has been jettisoned during the journey through the Martian atmosphere to the planet's surface. It will take 15 images at 1.5 s intervals, and these images will be stored in local memory. To avoid electrostatic discharges affecting the instrument, there will be a delay of several minutes after Schiaparelli has landed on the surface of Mars, before the data are read out by Schiaparelli's computer and subsequently downlinked to Earth.


*Schiaparelli - without heat shield and back cover. Credit: ESA/ATG medialab*

DECA was designed and built by Optique et Instruments de Précision (OIP) in Belgium for ESA and provided to the ExoMars mission by the Scientific Support Office.